

MAXIMIZATION OF SOCIAL WELFARE CONSIDERED TOLL AND TAX (Incheon International Airport Expressway VS Incheon Bridge)

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Abstract

Based on case study of the Incheon International Airport Expressway that is the first private capital road in South Korea and the Incheon Bridge that will be open for traffic in 2010, we knew the maximization of social welfare considered toll and tax on a point of view social surplus. And considered the strategy situation that Incheon International Airport Expressway and the Incheon Bridge should be calculated the expecting response of competitor under the alternative (choose the toll or tax) is not yet determined each other, what is the best alternative plan, how much the quantity of each social surplus, and what strategy will be maximize social welfare applying the game theory based on Nash Equilibrium.

Key Words : Toll, Tax, Surplus, Social welfare, Game theory

1. INTRODUCTION

Under the ongoing economic growth, traffic demand was rapidly increasing with various economic activities and leisure activities. To handle the increased traffic demand of various purposes, the supply of transportation facilities is urgently required.

But the limit of investment funds on public sector for facility supply, the government decided that using private capital secured the investment funds is resonable. So until now, South Korea has actively encouraged private capital.

This research will show the maximization of social welfare in terms of social surplus and target area is the first private capital road Incheon International Airport Expressway(a toll road, opened in December 2000) and Incheon Bridge(will be open in 2010).

Also, considered the strategy situation that Incheon International Airport Expressway and the Incheon Bridge should to calculate the expected response of competitor under the alternative(choose the toll or tax) is not yet determined each other, what is the best alternative plan, how much the quantity of each social surplus, and what strategy will be maximize social welfare applying the game theory based on Nash Equilibrium.

2. THEORY

2.1 Toll and Tax

Generally, toll is used to limit the traffic, and obtain of new infra-structure's financial resources. Based on this mechanism, the toll is widely used around the world as Singapore, Norway, Japan include South Korea. Toll is to pay fixed money or currency for special services or rights. Also toll is the typical way for directly charged for the road can use.

Typically, tax is fixed currency for common services or right such as the support of government or road, and it is indirectly way to charge.

In other words that will depend on "How provided user the special or generally service about difference of toll and tax?" and "How much correlate with revenues mechanism?"

2.2 Surplus

2.2.1 Producer Surplus

If, the production conditions of each producer are different each other and Principle of 'Low of one price' is exist in the market, production prices of each producer is determined by production costs of producer who has the most disadvantageous production conditions. As a result, producers who have favorable production conditions will be able to have surplus than the disadvantaged producers. This surplus is called the producer surplus.

Producer surplus is caused by production costs and advantage of management. Producer surplus is accounted for important position on theory of distribution and had more important meaning on taxation theory. When assess to producer without price increases, the tax is a way on the producer surplus. For example, excess-profit tax is in this case that assess special-tax to producer who had the benefit of more regular basis.

2.2.2 Consumer Surplus

Consumers surplus means, when consumer purchased goods a lower price, even if consumer want to get paid a higher price, welfare or surplus-satisfaction from it.

A. Marshall¹ defined consumers surplus that "the excess quantity that consumer want to pay price for goods over than actually paid price."

E. J. Dupuit² mentioned that "Economics is the effectiveness measure of a thing, each consumer should be bear most of the willingness to pay sacrifice for obtain it."

2.2.3 Social Surplus

Social surplus is defined the sum of producer surplus and consumers surplus as Figure 1 and regarded maximization of social surplus as maximization of social welfare in this research.

¹ Marshall, A.(1920), "Principle of Economics", 8th ed.

² Dupuit. E.J.(1844), "De la mesure de l'utilite des travaux publics".

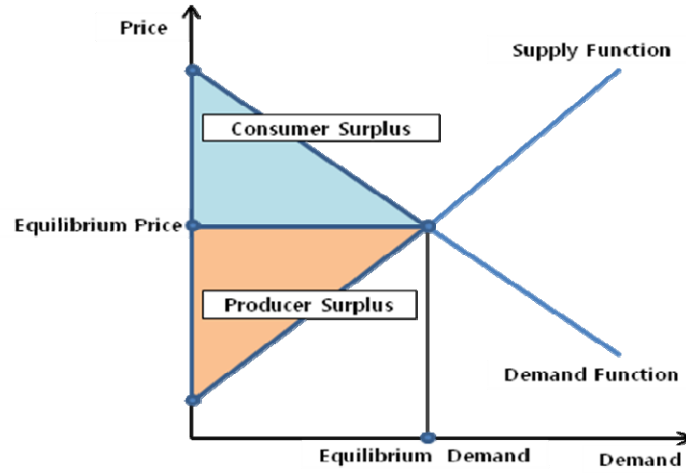


Figure 1 Consumer Surplus

2.3 Maximization of Social Welfare

In this research used an object function as Equation 1 for maximization of social welfare and regarded maximization of social welfare as maximization what sum of producer surplus and consumer surplus.

Consumer surplus and producer surplus is the inseparable relationship. So, it is a self-evident that, if consumer surplus increased, producer surplus decreased. Conversely, if producer surplus increased, consumer surplus decreased.

In this research, find a maximum point that is sum of producer surplus and consumer surplus under the circumstance of toll and tax in Incheon International Airport Expressway and Incheon Bridge.

$$Max_{\tau, \chi} W = \Pi_i + U(F_i, M_i) \quad (1)$$

Π_i = Producer surplus(revenue) of region i

U = Consumer surplus function of region i

F_i =Traffic demand of region i

M_i =Non-traffic consumption by residents of region i

τ =Toll

χ =Tax

2.4 Game Theory

From the perspective of game theory, game means competitive situation that more than one subject of the economy pursue own interests through a mutual association, but no one, it does not know result.

In reality, character of game is existing strongly on competition between companies. Elements of the game are the player (New Airport Hiway Corporation and Incheon Bridge Corporation), strategy(toll or tax), and payoff of game(procurable social surplus when player select toll or tax). So it depend on how these elements are verified, determine the characteristics of game.

2.4.1 Nash Equilibrium

When players choose the best strategy under the each player thought that strategy is given to other player, this pair of optimal strategies are called "Nash Equilibrium." For example, let assuming that

when New Airport Hiway Corporation think without own profits, approach the Nash Equilibrium, if actually New Airport Hiway Corporation charged toll by strategy of toll, revenue will not be change the tax, the toll does not change, and this strategy can be maximum of social surplus.

If so, Incheon Bridge Corporation select optimal strategy(toll or tax) that can be maximum of social surplus against toll strategy of New Airport Hiway Corporation, this pair of the optimal strategy(New Airport Hiway Corporation's strategy is toll, Incheon Bridge Corporation's strategy is toll or tax) is Nash Equilibrium.

2.4.2 Positive Game

About traffic volume that pass through the Incheon International Airport Expressway and Incheon Bridge, regard as 'positive game'.

If players gained the sum of compensation is to be correspond with certain number on some game, this game is 'positive game'. For example, given the size of the market, if the situation that players are competing for big market occupancy percentage, is 'positive game'.

In the case of any strategy, sum of Incheon International Airport Expressway's traffic and Incheon Bridge's traffic is constant as equation 2. The case of exceptions exists. For example, if the New Airport Hiway Corporation and Incheon Bridge Corporation choose the tax, traffic of Incheon's downtown and outskirts of Gyeon-gi transfer to Incheon International Airport Expressway or Incheon Bridge. It based on charged the road pricing by tax indirectly. Actually, sum of analyzed AADT is Table 1 on each strategy.

$$F_{IAE} + F_{IB} = \text{const} \quad (2)$$

F_{IAE} = traffic of Incheon International Airport Expressway

F_{IB} = traffic of Incheon Bridge

Table 1 Sum of AADT on each strategy

Player	New Airport Highway Corporation (Incheon International Airport Expressway)		
	Strategy	Tax	Toll
Incheon Bridge Corporation (Incheon Bridge)	Tax	281,345 vpd	150,332 vpd
	Toll	150,332 vpd	150,332 vpd

3. DATA COLLECTION AND HANDLING

3.1 Data Collection

In this study, data was based on 『Modification and complement research of preliminary feasibility study standard instructions on the road and railway (4th edition), the Korea Development Institute, 9. 2004』 .

To estimate the producer surplus, used data of maintenance costs. To estimate the consumer surplus, used data of vehicle operation cost and value of travel time for business and non-business. Data of network and origin-Destination was based on resources of Seoul Development Institute(3rd edition). And internal resources of New Airport Hiway Corporation was used.

3.2 Data Handling

If strategy is road pricing, data is consist on toll (PCU unit converted to toll) for deriving benefit items, construction and maintenance cost for deriving costs items of producer surplus, vehicle operation cost/value of time for deriving consumer surplus.

IF strategy is tax, data are consist on oil tax, private auto tax of residents, property tax, inhabitants tax for deriving benefit items, construction and maintenance cost for deriving costs items, and vehicle operation cost/value of travel time for deriving consumer surplus.

3.2.1 Producer Surplus

1) Toll

IF strategy is road pricing, benefit item of producer surplus is toll. Average toll (New airport office: ₩6,800, North Incheon office: ₩3,350)³ was applied on Incheon International Airport Expressway and based on general passenger car toll(₩4,500, ₩500 units by 4,500 to change the circle) of actual agreement was applied on Incheon Bridge.

2) Oil tax

IF strategy is tax, benefit of producer surplus is oil tax.

For oil tax applied to Incheon International Airport Expressway (New Airport Office~Airport New City I.C(18.6km), North Incheon Office~Airport New City IC(12.3km)) and Incheon Bridge(12.3km), selected oil price of vehicle operation cost, and derived oil price and tax based on the Korea Oil Association data(2006).

3) Residents tax

IF strategy is tax, another benefit of producer surplus is tax of residents. Yeong-jong-do is in Jung-gu, Incheon city, and Yeong-jong-do is divided into Yeong-jong-dong and Yong-yu-dong.

Based on total tax of Jung-gu, total population of Yeong-jong-dong/Yong-yu-dong, total population of Jung-gu in 2006, private auto tax of residents, property tax and inhabitants tax estimated in Yeong-jong-dong and Yong-yu-dong.

Under the assumption that is the growth ratio of AADT on Incheon International Airport Expressway in 2006 and estimated AADT of Transcad programming analysis in 2011, population will be grow, estimate residents tax in Yeong-jong-dong and Yong-yu-dong, 2011.

4) Road construction cost

Cost item of producer surplus is road construction cost. For estimate construction cost about analysis section, among total construction cost consider the distance of total and distance of analysis section, applied same depreciation cost for 30 years was regarded the road construction cost.

Table 2 is total construction cost and construction cost of analysis section about Incheon International Airport Expressway and Incheon Bridge.

Table 2 Total construction cost and construction cost of analysis section about Incheon International Airport Expressway and Incheon Bridge.

(unit: 1 million ₩(won))

	Incheon International Airport Expressway	Incheon Bridge
total construction cost	1,425,970	1,096,100
Proportional to the distance construction costs	659,777	
depreciation cost (unit:year)	21,993	36,537

5) Maintenance cost

To estimate for annual maintenance cost about Incheon International Airport Expressway and Incheon Bridge, used the maintenance cost estimation section of 『Modification and Complement Research of Preliminary Feasibility Study Standard Instructions on the Road. Railway(4th edition), the Korea

³ ₩(won) is currency unit of South Korea Exchange rate(2009. 01. 28):₩1,000(KRW) ÷ \$0.73(USD).

Development Institute, 9. 2004』 . And considering the distance and lane of section, compensate the maintenance cost.

3.2.2 Consumer Surplus

1) Vehicle operation cost

To estimate for annual vehicle operation cost about Incheon International Airport Expressway and Incheon Bridge, used the vehicle operation cost estimation section of 『Modification and complement research of preliminary feasibility study standard instructions on the road and railway (4th edition), the Korea Development Institute, 9. 2004』 .

Using data of the National Statistical Office, revised the vehicle operation cost from 2003 to 2006. Vehicle operation cost is composed of oil cost, engine oil cost, tire cost, maintenance cost, depreciation cost.

2) Value of travel time

To estimate for annual value of travel time about Incheon International Airport Expressway and Incheon Bridge, used value of business and non-business travel time estimation section of 『Modification and complement research of preliminary feasibility study standard instructions on the road and railway(4th edition), the Korea Development Institute, 9. 2004』 . And using the revised data in 2006, estimated the value of average travel time for passenger car, taxi, bus and truck.

4. ANALYSIS

4.1 Analysis Method

Based on collected and handled data, estimate traffic volume classified by strategy(toll and tax), using Table 3 and Transcad 4.7 program. “What is the best alternative plan?”, “How much the quantity of each social surplus?”, and “What strategy will be maximize social welfare?” for each player (Incheon International Airport Expressway and Incheon Bridge).

Table 3 Revenue mechanism		
Incheon International Airport Expressway	Tax	Toll
Incheon Bridge	$[P_0^{\chi\chi}, P_1^{\chi\chi}]$	$[P_0^{\chi\tau}, P_1^{\chi\tau}]$
Tax		
Toll	$[P_0^{\tau\chi}, P_1^{\tau\chi}]$	$[P_0^{\tau\tau}, P_1^{\tau\tau}]$

P_0 = Incheon International Airport Expressway

P_1 = Incheon Bridge

τ = Toll

χ = Tax

4.2 Result of Analysis

4.2.1 Incheon International Airport Expressway(Toll) VS Incheon Bridge(Toll)

When Incheon International Airport Expressway and Incheon Bridge equally collected toll, analyze the change of demand and social welfare.

First, analyzed the change of social welfare on condition that fixed the toll(New Airport Office:₩6,800, North Incheon Office:₩3,350, the basic year : 2006) of Incheon International Airport Expressway and change the toll(₩3,500~₩5,500) of Incheon Bridge.

Also, analyzed the change of social welfare on condition that fix the toll(~~₩4,500~~→₩500) of Incheon Bridge and change the toll(5%, 10%, 15% raising or reduction, the basic year : 2006).

1) Incheon International Airport Expressway (fix) VS Incheon Bridge (change)

According to change of the Incheon Bridge's toll(~~₩5,500~~→₩3,500), Incheon Bridge's demand increased and Incheon International Airport Expressway's demand decreased. By these change, total producer surplus decreased and total consumer surplus increased.

Result of analysis is as follows. Total consumer surplus increased, because decrease of travel time by decrease of demand and increase of vehicle speed. When Incheon Bridge choose the toll of ₩3,500, sum of the total producer surplus and total consumer surplus is maximum.

Table 4 Social Surplus

(unit : 1 million ₩(won)/day)					
Toll	₩5,500	₩5,000	₩4,500	₩4,000	₩3,500
Social Surplus	-238	-240	-238	-239	-207

2) Incheon International Airport Expressway(change, raising or reduction) VS Incheon Bridge(fix)

Result of analysis, if the toll(~~₩4,500~~→₩500) of Incheon Bridge is fixed and the toll(5%, 10%, 15% raising or reduction) of Incheon International Airport Expressway is changed, avoiding traffic of Incheon Bridge is exist by user transfer Incheon Bridge to Incheon International Airport Expressway.

But elasticity of transition demand is insignificant about fluctuation of toll on Incheon International Airport Expressway.

Table 5 Social Surplus

(unit : 1 million ₩(won)/day)				
Toll Incheon Bridge :fix (₩4,000)	Incheon International Airport Expressway			
	Raising			
	5%	10%	15%	
Social Surplus	-289	-342	-387	
	Reduction			
	5%	10%	15%	
	-237	-237	-237	

4.2.2 Incheon International Airport Expressway(Tax) VS Incheon Bridge(Toll)

According to variation of toll(~~₩5,500~~→₩3,500) and demand on Incheon Bridge, demand of Incheon International Airport Expressway gradually decrease and total producer is decreasing.

The reason is as follows. According to demand of Incheon International Airport Expressway decrease, finally sum of oil tax is decrease, although the strategy of Incheon International Airport Expressway is tax(not collect toll). But total producer is increasing again on the section of ₩4,000~₩3,500.

In contrast, total consumer surplus is increasing on the section of Incheon Bridge's toll(~~₩5,500~~→₩4,000) and decreasing on the section of toll(₩4,000~₩3,500).

The reason for the increase in total consumer surplus, influence of reduced travel time by increasing of vehicle speed(demand is decreasing). In spite of indirect toll levied by tax on Incheon International Airport Expressway, demand of Incheon International Airport Expressway is decrease by variation of toll on Incheon Bridge. It is shows that the demand of Incheon Bridge exist, if another something benefit exist, willing to charge the toll anyhow.

When Incheon Bridge choose the toll of ₩5,500, sum of the total producer surplus and total consumer surplus is maximum. The reason is as follows. Even if Incheon International Airport Expressway choose the tax, a lot of demand exist. And consequently cover the fixed costs on Incheon International Airport Expressway, also road users don't pay toll.

Table 6 Social Surplus

(unit : 1 million ₩(won)/day)

	Toll of Incheon Bridge				
	₩5,500	₩5,000	₩4,500	₩4,000	₩3,500
Social Surplus	610	591	556	535	520

4.2.3 Incheon International Airport Expressway(Toll) VS Incheon Bridge(Tax)

Traffic of Incheon International Airport Expressway clearly was reduced by tax strategy of Incheon Bridge. Value of total producer surplus is positive and value of total consumer surplus is negative. The reason of negative value's total consumer surplus is influenced by toll.

And sum of the total producer surplus and total consumer surplus(social surplus) is negative value. Because profit quantity of total consumer surplus is clearly lower than loss quantity of total producer surplus.

Traffic is obvious high for Incheon Bridge than charging the toll. But Total producer surplus is negative by tax. This is the reason that revenue of oil tax does not cover the fixed costs.

Total consumer surplus is positive value. This is the reason that, although traffic speed is reduced than strategy is toll, but road users do not pay the toll. And sum of the total producer surplus and total consumer surplus(social surplus) is positive value. Because, s profit quantity of total consumer surplus is far higher than loss quantity of total producer surplus.

Table 7 Social Surplus

(unit : 1 million ₩(won)/day)

	Incheon International Airport Expressway	Incheon Bridge
Social Surplus	-131	224
Total	93	

4.2.4 Incheon International Airport Expressway(Tax) VS Incheon Bridge(Tax)

If Incheon International Airport Expressway choose the tax strategy, traffic increase sharply. In this case, traffic is higher than situation that tax of Incheon International Airport Expressway and toll of Incheon Bridge. The reason is that to avoid the traffic jams of the downtown area, bypass traffic rapidly increase by Incheon International Airport Expressway and Incheon Bridge does not charge toll.

Sum of the total producer surplus and total consumer surplus(social surplus) is positive value. In spite of Incheon International Airport Expressway does not charge toll directly, total producer surplus is positive value by high traffic(fill up of oil tax). Also total consumer surplus is positive value, because in spite of traffic speed decrease by high traffic, it does not charge the toll. Sum of the total producer surplus and total consumer surplus(social surplus) is positive value.

Also, if Incheon International Airport Expressway choose the tax strategy, traffic increase sharply, also. In this case, traffic is higher than situation that toll of Incheon International Airport Expressway and tax of Incheon Bridge. The reason is that to avoid the traffic jams of the downtown area, bypass traffic rapidly increase by Incheon International Airport Expressway and Incheon Bridge does not charge toll. But total producer surplus is still negative value. Because total of oil tax is less than fixed costs(construction cost and maintenance cost).

Total consumer surplus is positive value, because Incheon Bridge choose the tax strategy, in spite of traffic speed decrease by increasing traffic. In spite of traffic increase, total producer surplus is negative value and total consumer surplus is positive value. So, profit quantity of total consumer surplus is higher than loss quantity of total producer surplus.

As a result, sum of the total producer surplus and total consumer surplus(social surplus) is positive value.

Table 8 Social Surplus

(unit : 1 million ₩(won)/day)

	Incheon International Airport Expressway	Incheon Bridge
Social Surplus	536	286
Total	822	

5. RESULTS AND FUTURE STUDY

5.1 Results

This research showed the maximization of social welfare in terms of social surplus and target area is the first private capital road Incheon International Airport Expressway(a toll road, opened in December 2000) and Incheon Bridge(will be open in 2010).

Also, considered the strategy situation that Incheon International Airport Expressway and the Incheon Bridge should to calculate the expected response of competitor under the alternative(choose the toll or tax) is not yet determined each other, what is the best alternative plan, how much the quantity of each social surplus, and what strategy will be maximize social welfare applying the game theory based on Nash Equilibrium.

The result is presented the combination considered social welfare at the national level as Table 9.

Table 9 Combination considered social welfare
[Incheon International Airport Expressway, Incheon Bridge]

(unit: 1 million ₩(won)/day)

Player	Strategy	New Airport Hiway Corporation (Incheon International Airport Expressway)	
		Tax	Toll
Incheon Bridge Corporation (Incheon Bridge)	Tax	[536 : 286]	[-136 : 224] (Toll of Incheon International Airport Expressway : ₩6,800 , ₩3,350)
	Toll	[527 : 83] Toll of Incheon Bridge: ₩5,500)	[-120: -87] (Toll of Incheon International Airport Expressway : ₩6,800 , ₩3,350 , Toll of Incheon Bridge: ₩3,500)

Based on Table 9, sum of social surplus is presented as Table 10.

Situation that is Incheon International Airport Expressway chose tax and Incheon Bridge chose too, is good from the viewpoint of social welfare. It should be approached that if the social overhead is invested by government, less the stress about toll for road users then, road user increased. At this time, social overhead capital is used the most efficiently.(also expressway invested by government charge the toll but, less than toll of expressway by private capital).

Table 10 Social surplus

(unit : 1 million ₩(won)/day)

Player	New Airport Hiway Corporation (Incheon International Airport Expressway)		
	Strategy	Tax	Toll
Incheon Bridge Corporation (Incheon Bridge)	Tax	[822]	[94]
	Toll	[610]	[-207] (Based of Figure) [-388](Considered actual condition)

The second best policy is that Incheon International Airport Expressway chose tax, Incheon Bridge chose toll. The third best policy is that Incheon International Airport Expressway chose toll, Incheon Bridge chose tax. The fact shows that fundamental demand of Incheon International Airport Expressway is more than Incheon Bridge's. Also more demand concentrate on Incheon International Airport Expressway under the situation that Incheon International Airport Expressway choose the tax and Incheon Bridge choose toll.

If Incheon International Airport Expressway and Incheon Bridge choose the toll, social surplus incur a loss. The reason is that producer surplus much increased at toll strategy, but profit of producer surplus does not cover the loss of consumer surplus.

If each player charged indirectly, tax for using road, social surplus is maximum, but producer will be showed a loss and government must give a lot of subsidy as actual agreement money.

Actuality, toll is the best strategy for each palyer. And analysis showed that optimum toll price was Incheon International Airport Expressway(New Airport Office: ₩6,800, North Incheon Office: ₩3,350) and Incheon Bridge(₩3,500). But appling these toll will be impossible in 2011. If reduce the toll of Incheon International Airport Expressway, it is the best for social surplus. But it has also a limit.

Actuality, government gave the subsidy (₩99,651,901,000, based on an audit report on financial statements of New Airport Hiway corporation in 2006) to New Airport Hiway corporation. If levy the money as subsidy to road users for mitigation of government subsidy that is growing snowballs, road users should to pay the addition toll(₩900,000) per 1PCU. It is impossible in reality a self-evident fact.

Accordingly, in this research the toll of Incheon International Airport Expressway in 2011 will not be same price of toll in 2006, and consider that toll will be ₩4,500 on Incheon Bridge at opening time, and if the toll of Incheon International Airport Expressway will increase equally(considered the average raising percentage(2.94%) from 2005 to 2007), and apply the ₩4,500 on Incheon Bridge, estimating social surplus is ₩-388,130,812/day.

If these two private capital road have no choice but to select the strategy of toll, and producer revenue cannot be guaranteed amount of the money as actual agreement with government without subsidy, there is no alternative without that two corporation will levy increasing toll by "principle of user charge". But to charge the minimum toll is to maximize the social welfare because, approach the social welfare viewpoint in this research.

5.2 Future Study

In this reaserch, analyzed the change of social welfare on condition that fixed the toll(New Airport Office: ₩6,800, North Incheon Office: ₩3,350, the basic year : 2006) of Incheon International Airport Expressway and change the toll(₩3,500~₩5,500) of Incheon Bridge. And analyzed the change of social welfare on condition that fix the toll(₩4,500±₩500) of Incheon Bridge and change the toll(5%, 10%, 15% raising or reduction, the basic year : 2006).

But in this case, it has limiting number of circumstance. Accordingly studies that considered variation of charge widely is desirable and these studies should be continued. This research included some

worry that drawn different from reality by applying a lot of assumptions. So data and study of more correct and particular is required and through that, the results of a more detailed analysis is expected to be drawn.

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